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Combining ability analysis for grain yield and its components in chickpea (*Cicer arietinum* L.)

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Abstract
In the present investigation, seven chickpea genotypes and their twenty one crosses (excluding reciprocals) were grown at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, in Randomized Block Design (RBD) with three replications. Combining ability analysis was carried out in 7 x 7 parental half diallel fashion for grain yield and its components in chickpea. General combining ability and specific combining ability variances were highly significant for all the characters indicating importance of both additive as well as non-additive type of gene actions in the inheritance of studied traits i.e., days to 50% flowering, days to maturity, plant height, plant spread, number of primary branches per plant, number of secondary branches per plant, number of fruiting branches per plant, number of pods per plant, number of seeds per plant, 100 seed weight and seed yield per plant. The parent Phule Vikram, JAKI-9218, Digvijay and GNG-2207 were high yielding with good general combining ability for grain yield per plant and some of its components, which can be used in future hybridization programme. Whereas, the crosses GNG-2207 X Digvijay, Digvijay x WR-315 and Phule Vikram x Digvijay recorded the highest sca effects. These crosses should be exploited for obtaining recombinants in advance segregating generations.

Keywords: Combining ability, GCA, SAC, chickpea

Introduction
Chickpea (*Cicer arietinum* L.) is an important grain legume in India and plays a dominant role in the agriculture of rainfed areas of the country. It is third most important pulse crop after dry bean and pea. Chickpea is the only cultivated species under the genus '*Cicer'*, and has 2n = 2x = 16 chromosomes with relatively small genome size of 738.09 Mbp (Varshney *et al.*, 2013) [13]. The important chickpea growing countries are India, Pakistan, Turkey, Iran, Mexico, Myanmar, Ethiopia, Australia and Canada. In India, chickpea is cultivated on an area of 10.43 million hectares with production of 11.10 million tonnes and productivity of 1064kg/ha while in Maharashtra it is grown on an area of 18.48 lakh ha with production of 18.91 lakh tonnes and having productivity of 1023 kg/ha (2017-18). The ability of parent to combine will depend on complex interaction among genes, which cannot be predicted from yield performance and adaptability of parents (Kumar *et al* 1999) [7]. The study of combining ability help in isolating useful parental lines and desirable specific cross combinations which could be further exploited in development of improved varieties (Sindhu *et al*. 2000, Patil *et al*. 2004) [12, 10]. The lines, which perform well in combination, are eventually of great importance to the plant breeders. Hence, investigation on general and specific combining ability would give very useful information. The present investigation aims at identification of superior parents, cross combination and evaluation of type of gene action for grain yield and as well as their respective components.

Materials and Methods
The experiment was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. Seven genotypes (JG-62, C-565, GNG-2207, Phule Vikram, Digvijay, JAKI-9218 and WR-315) of chickpea were chosen and crossed in 7 x 7 half diallel mating design excluding reciprocals. The complete set of 28 genotypes comprising seven parental genotypes and their 21 F_1's were evaluated in Randomized Block Design with three replications during rabi season, 2017-18. Each plot consists of single row of three meter length. The inter row and intra row spacing was 30 and 10 cm, respectively. The observations were recorded from randomly selected five competitive individual plants *viz.*, days to 50% flowering, days to maturity, plant height (cm), plant spread (cm), number of primary branches per plant, number of secondary branches per plant, number of fruiting branches per plant, number of pods per plant, number of seeds per plant, number of seeds per pod, 100 seed

weight (g) and seed yield per plant (g). All the agronomic practices were followed to raise a good crop. Combining ability analysis was carried out according to Griffing (1956a) [3] as per Model I and Method 2.

Results and Discussion

Analysis of variance for combining ability (Table 1) showed that general and specific combining ability variances were highly significant for all the characters suggested importance of both additive and non-additive type of gene actions in the inheritance of characters. Similar results evincing involvement of predominance of additive and non additive gene effect in chickpea was reported by Chaturvedi *et al.* (1993) [1], Jeena and Arora (2001) [6] and Gupta *et al.* (2007) [4]. Most of the top ranking sca crosses had at least one good general combining ability parent and most of these crosses had high *per se* performance in respective traits. This indicated important role of additive X dominance or additive X additive gene interaction in high ranking sca effects of these hybrids. Thus, best cross combinations could be obtained by crossing at least one parent with good gca effect. High *per se* performances of crosses were thus related to the high sca effects and good gca effects of parents. Similar results for grain yield and component characters like number of pods per plant, number of seeds per pod and 100-seed weight were reported by Patil *et al*. (2004) [10] Jayalakshmi *et al*. (2009) [5] and Saxena and Ravindrababu (2017) [11].

Estimates of gca effects (Table 2) indicated that parent Phule Vikram was good general combiners for most of the characters. Thus the parental line Phule Vikram holds promise for genetic improvement of chickpea. The parent JAKI-9218 was good general combiner for days to 50% flowering, 100 seed weight and seed yield per plant. The parents JG-62 and C-565 were good combiner for days to 50% flowering and days to maturity so that they can be used as source of earliness in varietal development programme. The parent GNG-2207 was good combiner for plant spread, number of primary branches per plant, number of secondary branches per plant, number of fruiting branches per plant, number of pods per plant, number of seeds per plant and number of seeds per pod. The parent Digvijay was exhibited good general combiners for number of secondary branches per plant and 100 seed weight.

Three best crosses selected on the basis of sca effects for each of the characters are presented in Table 3. A perusal of data reveled that none of the crosses was high ranking for all the characters. The sca for most of the characters where accompanied by top ranking *per se* performance also indicating predominant role of non-additive gene effects in expression of grain yield and its components. For grain yield per plant, it was observed that the crosses GNG-2207 x Digvijay followed by Digvijay x WR-315 and Phule Vikram x Digvijay recorded the highest sca effects and also top ranking in *per se* performance and they involved good x good gca of the parents. The preponderance of general combining ability and specific combining ability for yield and yield contributing characters in chickpea were also reported by Gautam and Gupta (2007) [4], Gupta *et al*. (2007) [4], Kumar *et al.* (1999) [8], Mali *et al.* (2006) [9], Patil *et al*. (2004) [10] and Saxena and Ravindrababu (2017) [11].

The combining ability also elucidates the nature of gene action involved in the inheritance of the nature of gene action for yield and its component characters has a bearing on the development of efficient breeding procedures. The general combining ability is attributed to additive, high degree of additive X additive interaction which is fixable in nature. On the other hand specific combining ability is attributed to non additive gene action and non fixable.

Table 1: Analysis of variance for combining ability for various characters in chickpea.

		Mean sum of squares					
Sources of Variation	**d. f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Plant spread (cm)**	**No. of primary branches per plant**	**No. of secondary branches per plant**
GCA	6	41.54**	55.18**	30.125**	4.395**	0.246**	3.988**
SCA	20	3.14**	6.83**	10.026**	2.586**	0.121**	2.615**
Error	54	0.729	2.162	4.582	0.675	0.019	0.230
σ^2 gca		4.535	5.891	2.838	0.413	0.025	0.417
σ^2 sca		2.410	4.670	5.443	1.911	0.102	2.384
σ^2 gca/ σ^2 sca		1.881	1.261	0.521	0.216	0.246	0.175

		Mean sum of squares				
Sources of Variation	**d. f.**	**No. of fruiting branches per plant**	**No. of pods per plant**	**No. of seeds per plant**	**100 seed weight (g)**	**Seed yield per plant (g)**
GCA	6	4.022**	224.623**	287.753**	45.815**	47.689**
SCA	20	2.271**	119.268**	165.749**	3.562**	36.156**
Error	54	0.163	1.095	12.218	0.477	0.235
σ^2 gca		0.428	24.836	30.615	5.037	5.272
σ^2 sca		2.108	118.17	153.53	3.085	35.921
σ^2 gca/ σ^2 sca		0.203	0.210	0.199	1.632	0.146

*,** Significant at 5 and 1 per cent level, respectively.

Table 2: Estimation of general combining ability (GCA) of parents for various traits of Chickpea.

Sr. No.	**Parents**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Plant spread (cm)**	**No. of primary branches per plant**	**No. of secondary branches per plant**
1	JG-62	-2.101**	-2.587**	-1.853**	-0.247	-0.025	-0.846**
2	C-565	-2.249**	-2.735**	-2.164**	-1.217**	-0.307**	-0.949**
3	GNG-2207	3.148**	3.709**	0.554	1.057**	0.167**	0.473**
4	Phule Vikram	-0.175	-0.735	3.392**	0.422	0.182**	0.784**
5	Digvijay	-0.508	-0.365	-0.083	0.190	0.026	0.362*
6	JAKI-9218	-0.767**	-0.143	0.340	-0.195	-0.077	-0.083

7	WR-315	2.381**	2.857**	-0.186	-0.032	0.034	0.258
SE (±)		0.2635	0.4537	0.6606	0.2534	0.0424	0.1481
CD at 5%		0.5270	0.9074	1.3212	0.5068	0.0848	0.2962
CD at 1%		0.6956	1.1978	1.7440	0.6690	0.1119	0.3910

Sr. No.	**Parents**	**No. of fruiting branches per plant**	**No. of pods per plant**	**No. of seeds per plant**	**100 seed weight (g)**	**Seed yield per plant (g)**
1	JG-62	-0.870**	-4.852**	-4.550**	-1.867**	0.658**
2	C-565	-0.914**	-6.345**	-6.522**	-1.020**	-2.964**
3	GNG-2207	0.508**	3.643**	5.341**	-2.074**	-2.371**
4	Phule Vikram	0.745**	8.465**	9.420**	0.302	3.916**
5	Digvijay	0.241	0.401	0.788	3.654**	0.023
6	JAKI-9218	-0.151	-0.654*	-2.819*	2.472**	1.190**
7	WR-315	0.441**	-0.657*	-1.659	-1.458**	-0.451**
SE (±)		0.1244	0.3229	1.0787	0.2130	0.1495
CD at 5%		0.2488	0.6458	2.1574	0.4260	0.2990
CD at 1%		0.3284	0.8525	2.8478	0.5623	0.3947

*,** Significant at 5 and 1 per cent level, respectively.

Table 3: Sca effects of top three best crosses having high sca effects along with *per se* performance for studied traits.

Characters	**Hybrids**	**SCA**	**GCA**	**Per se performance**
Days to 50% flowering	JG-62×C-565	-4.954**	A X P	50.67
	GNG-2207×JAKI-9218	-2.139**	G X G	57.00
	C-565×JAKI-9218	-1.806*	P X G	51.67
Days to maturity	Phule Vikram×Digvijay	-3.852**	G X G	109.00
	Phule Vikram×JAKI-9218	-2.741*	G X G	110.33
	JG-62×Phule Vikram	-1.963	A X G	108.67
Plant height (cm)	Digvijay×WR-315	5.043*	G X P	58.00
	GNG-2207×JAKI-9218	3.057	G X G	54.87
	C-565×WR-315	1.480	A X P	59.53
Plant spread (cm)	Phule Vikram×Digvijay	1.981**	G X G	18.13
	Digvijay×WR-315	1.522*	G X P	17.20
	C-565×GNG-2207	1.107	A X G	16.47
No. of primary branches per plant	Phule Vikram×Digvijay	0.466**	G X G	3.93
	C-565×WR-315	0.128	A X P	3.13
	Digvijay×WR-315	0.128	G X P	3.47
No. of secondary branches per plant	Phule Vikram×Digvijay	2.828**	G X G	15.53
	C-565×WR-315	1.198**	A X P	12.07
	GNG-2207× WR-315	1.376**	G X P	13.67
No. of fruiting branches per plant	Phule Vikram×Digvijay	2.802**	G X G	15.13
	GNG-2207× WR-315	1.572**	G X P	13.87
	Phule Vikram×JAKI-9218	1.261**	G X G	13.20
No. of pods per plant	Phule Vikram×Digvijay	19.469**	G X G	89.73
	C-565×GNG-2207	16.903**	A X G	75.89
	Phule Vikram×JAKI-9218	8.756**	G X G	77.78
No. of seeds per plant	Phule Vikram×Digvijay	24.081**	G X G	103.33
	C-565×GNG-2207	22.604**	A X G	90.47
	Digvijay×WR-315	9.293**	G X P	77.47
100 seed weight (g)	Digvijay×WR-315	3.643**	G X P	25.05
	Digvijay×JAKI-9218	1.689**	G X G	27.03
	JG-62×C-565	1.428*	A X A	17.74
Seed yield per plant (g)	GNG-2207×Digvijay	8.685**	G XG	28.43
	Digvijay×WR-315	7.529**	G X P	29.19
	Phule Vikram×Digvijay	6.962**	G X G	32.99

G = Good; A = Average; P = Poor.
*, ** indicates significant at P = 0.05 and P = 0.01 levels, respectively

Conclusion

Chickpea being a self-pollinated crop, the exploitation of heterosis is not feasible. However, the cross combinations with high sca, which involve at least one good general combiner, could throw up desirable transgressive segregants if the additive genetic system present in the good combiner and complementary epistatic effects act in the same direction to maximize the desirable plant attributes.

From the present study it is concluded that the parental genotypes Phule Vikram, JAKI-9218, Digvijay and GNG-2207 were found to be good general combiners for yield and most of its contributing characters. These parents may be used in future crossing programme of chickpea improvement. Similarly, the crosses GNG-2207 x Digvijay, Digvijay x WR-315 and Phule Vikram x Digvijay may be exploited to obtained transgressive segregants in advance generation.

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